Novel Voltage Mode Multifunction Filter based on Current Conveyor Transconductance Amplifier

Neeta Pandey, Sahil Kapur, Pushkar Arora, Sagar Malhotra
Department Of Electronics and Communication
Delhi Technological University
Delhi, India
Email: n66pandey@rediffmail.com
pushkar.arora@dce.edu

***Abstract*— This paper presents a novel voltage mode (VM) first order Single input three output multi function filter employing second generation current conveyor transconductance amplifier (CCII-TA). The proposed circuit employs only one active element, one grounded capacitor and three resistors. The angular pole frequency of the proposed circuits can be tuned electronically with the help of bias current. The proposed circuit is very appropriate to further develop into an integrated circuit. Sensitivity study is provided and SPICE simulations have been included which verify the workability of the circuit .**

***Index Terms*—Second-generation Multiple output current conveyor transconductance amplifier (CCII-TA), Analog Building Blocks (ABBs), filter.**

I. Introduction

In the field of electrical engineering, an analog filter is an important building block which is widely used for continuous-time signal processing. Of particular concern here are first order multifunction filters as they allow realization of different filter functions from the same topology thus facilitates the cost reduction involved in the integrated circuit manufacturing [1]. In the recent past a number of first order filters based on different active building blocks (ABB) have been proposed in the literature [2]-[13]. A close observation of these structures [2]-[13] reveals that the proposed circuits:

1. Do not have inherent electronic tuning properties [2]-[9].
2. Use floating capacitors [2], [5], [11]-[13] which is not desirable for IC implementation as unlike grounded capacitances they cannot compensate for stray capacitances at present at these nodes [14], [15].
3. Employ excessive number of passive components in [8]
4. Use multiple ABBs (Current Conveyors) in [9], [10].

These limitations make these circuits inappropriate for IC implementation as they occupy more chip area and have high power consumption. Recently, a modern active building block namely CCII-TA [16] has been proposed in the literature which is suitable for a class of analog signal processing which can operate in both current and voltage-modes, It possesses high dynamic range, high-slew rate, higher speed, low power consumption and wide bandwidth. Although a number of biquads [16], [17], [18] based on CCII-TA have been proposed, no first order multi function filter using this active element is available in open literature. The purpose of this paper is to present a novel multi function filter based on a single CCII – TA that employs a single CCII-TA and four passive components. The circuit uses all grounded capacitances, which is suitable for monolithic integration. This is because grounded capacitor circuit can compensate for the stray capacitances at their nodes [14], [15]. The angular pole frequency of the multi function filters can be tuned electronically by input bias current and the sensitivities are also less than or equal to unity. To verify the workability of the proposed circuits, simulations have been carried out using SPICE and results are included.

II. Proposed circuit

The CCII-TA essentially consists of a multiple output second-generation current conveyor (MO-CCII) at the front end and a balanced operational transconductance amplifier (BOTA) at the rear end. Recently, a practical implementation of simplified CCII-TA using commercially available active devices has been presented in [18]. The port relations of CCII-TA as shown in Fig. 1 may be expressed as:

$$I_Y = 0,\ V_X = V_{Y,}\ \ I_{Z1} = I_{Z2} = I_{Z3} \tag{1}$$

$$I_{0+} = -I_{0-} = g_m V_Z \tag{2}$$

The bipolar transistor based internal circuit structure of CCII-TA is shown in Fig. 2. The transconductance gm in (2) is controllable by bias current IB2 and is expressed as $g_m = I_{B2}/2V_t$, where V_t is the thermal voltage.

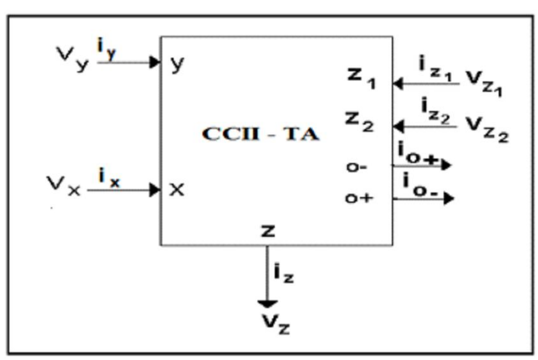

Figure 1. The circuit symbol of CCII-TA.

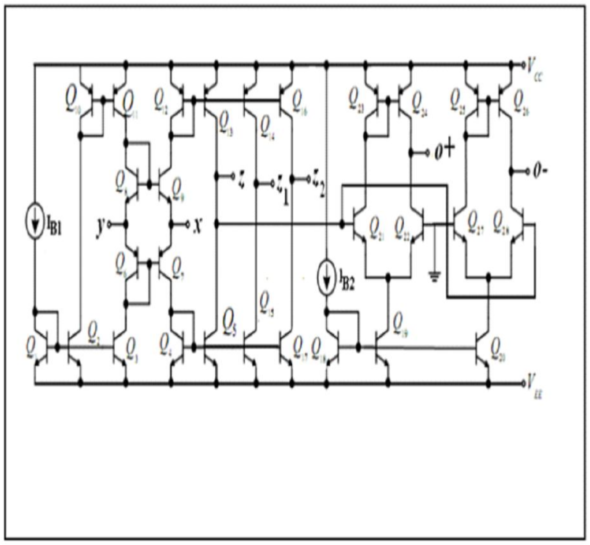

Figure 2. A possible bipolar implementation of the CCII-TA

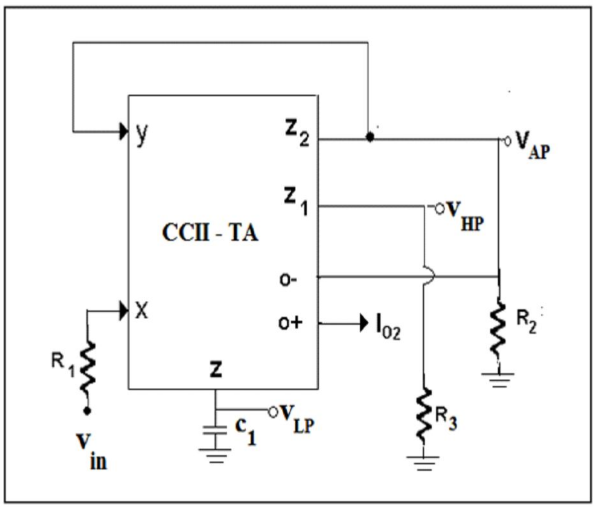

Figure 3. The proposed multi function filter using CCII-TA.

The proposed multifunction filter circuit based on CCII – TA is shown in Fig.3. Routine circuit analysis for R1 = 2 R2 yields the following transfer function.

$$\frac{V_{AP}}{V_{in}} = -\frac{s - g_m / C_1}{s + g_m / C_1} \tag{3}$$

$$\frac{V_{LP}}{V_{in}} = \frac{-1/C_1R_2}{s + g_m / C_1} \tag{4}$$

$$\frac{V_{HP}}{V_{in}} = \frac{sR_3}{R_2(s + g_m / C_1)} \tag{5}$$

$$\omega_0 = g_m / C_1 \tag{6}$$

$$\angle V_{AP}(j\omega) = -2\arctan(\omega C_1 / g_m) \tag{7}$$

$$\angle V_{LP}(j\omega) = 180° - \arctan(\omega C_1 / g_m) \tag{8}$$

$$\angle V_{HP}(j\omega) = 90° - \arctan(\omega C_1 / g_m) \tag{9}$$

Equation (6) reveals that pole frequency ω_0 can be adjusted by g_m, i.e. bias current of CCII – TA. It is clear that the transfer functions (3) to (5) are characterized by pole frequency as given in (6) and thus have electronically tunable characteristics.

For all three transfer functions the results of active and passive sensitivity analysis of various parameters are given as

$$S_{g_m}^{\omega_0} = 1,\ S_{c1}^{\omega_0} = -1,\ S_{R_1}^{\omega_0} = 0,\ S_{R_2}^{\omega_0} = 0,\ S_{R_3}^{\omega_0} = 0.$$

All active and passive sensitivities of pole ω_0 are low and less than or equal to unity in magnitude. Thus the proposed circuit can be classified as insensitive as all the active and passive sensitivities are inferior or equal to unity [19].

III. Design examples and simulation results

The multi function filter of Fig. 3 has been simulated using SPICE Circuit simulation program with typical parameters of bipolar transistors PR100N (PNP) and NR100N (NPN) [20] and DC supply voltage of +/-2V.The circuit has been designed to operate at a pole frequency of 80 KHz. The values of different components have been selected as: C_1=1nF, I_o= 13µA, R_1=2K, R_2=1K, R_3=1K.The magnitude response of the multi function filter has been shown in Fig. 4 and Fig. 5 shows the phase response of the filter.

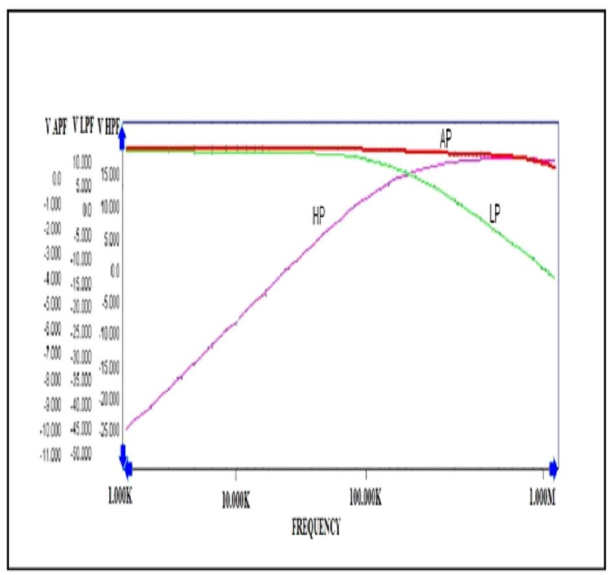

Figure 4. The frequency response of the proposed multi function filter.

DOI: 01.IJCSI.02.01.87

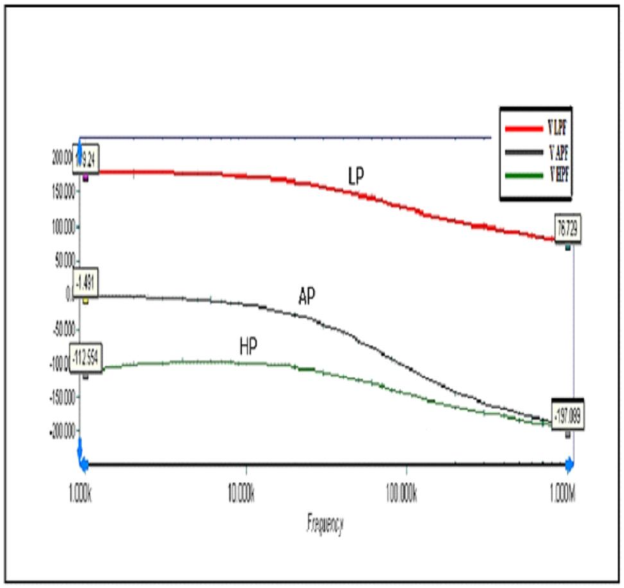

Figure 5. The phase response of the proposed multi function filter.

Magnitude and phase response of the high pass function of the multi function filter for different values of the bias current IB2 are shown in Fig. 6 and Fig. 7 respectively. Figure 8 shows the electronic tunability of the pole frequency of high pass filter. This graph is a straight line which confirms that there is a direct proportionality between the bias current and the pole frequency which has already been theoretically proved in this paper. All these simulated results confirm that the pole frequency can be electronically controlled by setting IB2. The simulated results are in close agreement with the theoretical results. The slight deviation from the ideal results can be attributed to the stray capacitances and other non idealities in the circuit elements.

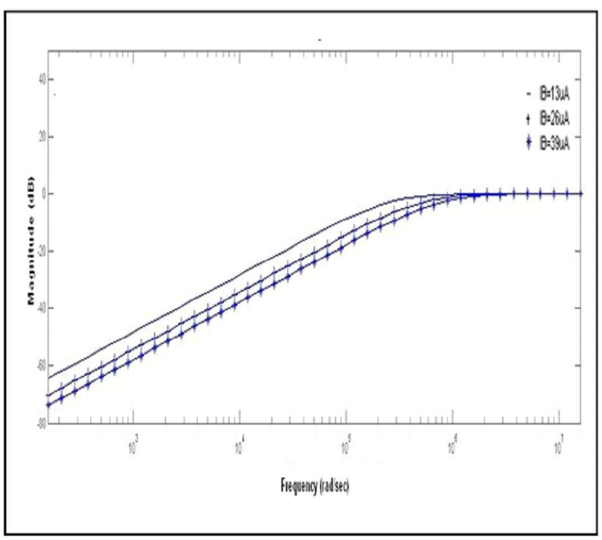

Figure 6. Magnitude response of high pass filter for different IB2.

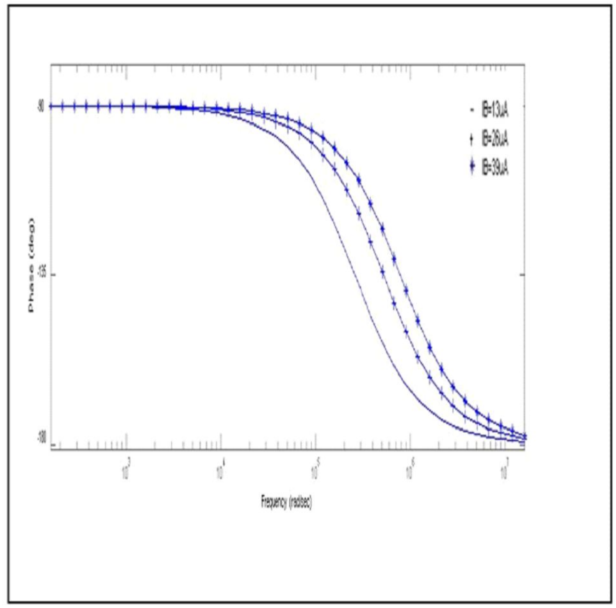

Figure 7. Phase response of high pass filter for different IB2.

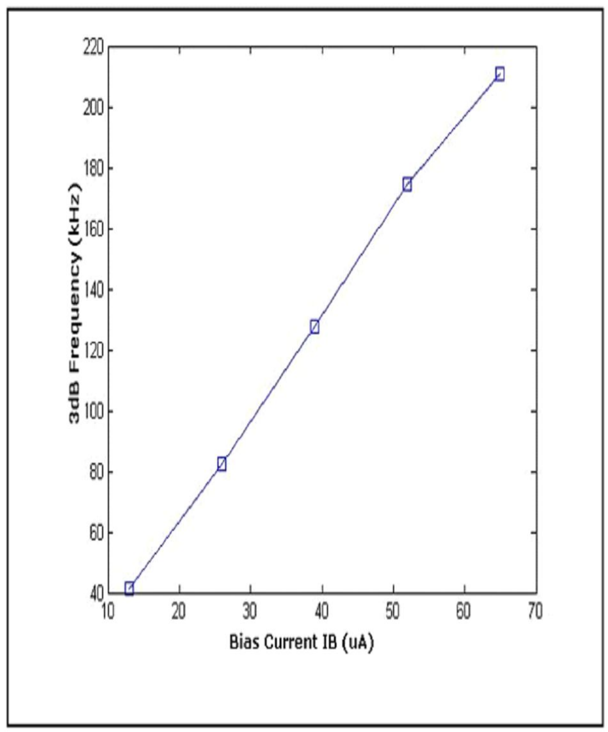

Figure 8. .Electronic tunability of pole frequency.

IV. Conclusion

A novel first order electronically tunable multi function filter has been presented in this paper. The circuit employs only a single active element, CCII-TA. It offers the advantage of electronic control of the pole frequency. The circuit also possesses low sensitivity performance. The circuit is suitable for IC implementation.

References

[1] Ferri, G., Guerrini, N. C. (2003). Low-voltage low-power CMOS current conveyors. London: Kluwer Academic Publishers.

[2] Cakir C., Cam U., Cicekoglu O., "Novel all pass filter configuration employing single OTRA," IEEE Transactions on Circuits and Systems-II, vol. 52, pp. 122-125, 2005.

[3] Salawu R.I., "Realization of an All-pass transfer function using the second generation current conveyor," Proceedings of the IEEE, vol. 68, issue 1, pp. 183-184, 1980.

[4] Horng, Jiun-Wei, "High input impedance first-order all pass, high pass and low pass filters with grounded capacitor using single DVCC," International journal of Engineering and materials sciences, vol. 17, pp.175-178, June 2009.

[5] Maheshwari S., "Voltage-mode all-pass filters including minimum component count circuits," Active and Passive Electronic Components, vol. 2007, Article ID 79159, 5 pages, 2007.

[6] Metin, B. Cicekoglu, O., "Novel Cascadable all pass filter with a grounded capacitor," Circuits and systems, MWSCAS'06 49TH IEEE International Midwest symposium, Volume: 2, pp. 242 – 244, 2006.

[7] Pal K., Rana S., "Some new first-order all-pass realizations using CCII," Active and Passive Electronic Components, vol. 27, pp. 91-94, 2004.

[8] Soliman A.M., "Generation of current conveyor-based all-pass filters from op amp-Based circuits," IEEE Transactions on Circuits and Systems-II, vol. 44, pp. 324-330, 1997.

[9] O. Cicekoglu and H.H. Kuntman, "CCII+ based first order all pass filters with all grounded passive elements," Proceeding of MELECON 1998, vol. 1, pp. 608-612,1998.

[10] Shah N. A., Iqbal S. Z. and Parveen B, " Simple first-order multifunction filter", Indian Journal of Pure & Applied Physics, Vol. 42, , pp. 854-856, November 2004.

[11] Maheshwari S., Khan I. A., "Novel first order all-pass sections using a single CCIII." International Journal of Electronics, vol. 88, no. 7, pp. 773-778, 2001.

[12] Higashimura, M., Fukui, Y., "Realization of all-pass networks using a current Conveyor," International Journal of Electronics, vol. 65, no.2, pp. 249-250,1988.

[13] Pandey N. and Paul S.K., "All-pass filters based on CCII- and CCCII- ", Int. J. Electronics, vol. 91, no. 8, pp. 485-489, 2004.

[14] Bhushan, M., Newcomb, R.W., "Grounding of capacitors in integrated circuits," Electronics Letters, vol. 3, p. 148-149, 1967.

[15] Soliman A. M., "New grounded capacitor current mode band-pass low-pass filters using two balanced output ICCII," Journal of Active and Passive Electronic Devices, vol. 3, p. 175-184, 2008.

[16] Prokop R., Musil V., "New modern circuit block CCTA and some its applications," Fourteenth International Scientific and Applied Science Conference - Electronics ET'2005, Book 5. Sofia: TU Sofia, pp. 93-98, 2005.

[17] Herencsar N, Koton J and Vrba K, "Single CCTA–Based Universal Biquadratic Filters Employing Minimum Components," International Journal Of Computer And Electrical Engineering, Vol.1, No.3, p. 309-312, August 2009.

[18] Jaikla, W., Silapan, P., Chanaprroma, C., Siripruchyanun, M., "Practical implementation of CCTA based on commercial CCII and OTA," Proceedings of International Symposium on Intelligent Signal Processing and Communication Systems, ISPACS 2008, Bangkok (Thailand), 2008.

[19] Fabre A., Dayoub F., Duruisseau L., Kamoun M., "High input insensitive second order filters implemented from current conveyor." IEEE Trans. Circuit Syst.-I, vol. 41, p. 918-921, 1994.

[20] Frey D. R., "Log domain filtering: An approach to current mode filtering", IEE Proceedings-Circuits, Devices and Systems, Vol. 140, pp. 406–416, 1993.

DOI: 01.IJCSI.02.01.87